ENERGY FOR DEVELOPMENT

The Potential Role of Renewable Energy in Meeting the Millennium Development Goals

REN21 Renewable Energy Policy Network for the 21st Century

Paper prepared for the REN21 Network by The Worldwatch Institute

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PREFACE

This paper was prepared for REN21, the Renewable Energy Policy Network for the 21st Century, which was an outcome of the Bonn International Conference for Renewable Energies in 2004. Formally established in Copenhagen in June 2005, REN21 provides a forum for international leadership on renewable energy and connects the wide variety of dedicated stakeholders that came together at the Bonn conference. At the G8 Summit in Gleneagles, Scotland, in July, heads of state issued a statement that embraced the role of REN21 in advancing new energy options.[1]

By sharing their experiences and expertise, the participants in REN21 seek to advance understanding of the potential contribution of renewable energy to achieving sustainable development. By identifying the wide variety of economical applications for renewable energy in developing countries, this report demonstrates the potential contribution of renewable energy to poverty alleviation and achievement of the United Nations Millennium Development Goals (MDGs).

Worldwide, 2.4 billion people rely on traditional biomass for cooking and 1.6 billion people do not have access to electricity. As stated by UN-Energy, this energy divide "entrenches poverty, constrains the delivery of social services, limits opportunities for women, and erodes environmental sustainability at the local, national, and global levels. Much greater access to energy services is essential to address this situation and to support the achievement of the Millennium Development Goals."[2]

At the World Summit on Sustainable Development (WSSD) in 2002, the global community agreed that renewable energy must be part of the solution. The Johannesburg Plan of Implementation, adopted at the WSSD, addresses renewable energy in several of its chapters. In Chapter II, on poverty eradication, governments agreed to improve access to reliable and affordable energy services for sustainable development, so as to facilitate the achievement of the MDGs. This included actions to increase the use of renewables.

In Chapter III, on sustainable consumption and production patterns, governments agreed to boost substantially the global share of renewable energy sources, with the objective of increasing the contribution of renewable energy to total energy supply. They recognized the role of national and voluntary regional targets and initiatives, and the need to ensure that energy policies support developing countries' efforts to eradicate poverty.[3]

This paper explores the extent to which increased use of renewable energy can provide reliable and affordable energy services, and assist developing countries in expediting their economic development and alleviating poverty. While the paper's contents have benefited from expert knowledge of the REN21 Steering Committee members, it cannot be considered representative of all views or of a consensus on each point.

Dr. Rajendra K. Pachauri
Chairman of REN21

Solar water pumping in Mali

EXECUTIVE SUMMARY

Affordable energy services are among the essential ingredients of economic development, including eradication of extreme poverty as called for in the United Nations Millennium Development Goals (MDGs). Modern energy services—mainly provided by liquid and gaseous fuels, as well as electricity—are essential for building enterprises and creating jobs. Convenient, affordable energy is also important for improving health and education, and for reducing the human labor required to cook and meet other basic needs.

Meeting these essential energy needs economically and sustainably requires a balanced energy portfolio that is suited to the economic, social, and resource conditions of individual countries and regions. This paper concludes that in many circumstances, renewable energy sources such as wind, solar, hydro, geothermal, and bioenergy have an important role to play, alongside fossil fuels, in an energy portfolio that supports achievement of the MDGs.[†]

Roughly 1.6 billion people worldwide do not have access to electricity in their homes, representing slightly more than one quarter of the world population. The 2.4 billion people who rely on traditional biomass fuels for their energy must collect and burn straw, dung, and scraps of wood to cook their meals. They often go without refrigeration, radios, and even light. The International Energy Agency estimates that if the MDG poverty-reduction target is to be met, modern energy services will need to be provided to an additional 700 million people by 2015.

In recent decades, the energy needs of poor people have been met most often via petroleum-based liquid fuels and by extension of the electricity grid, which is powered mainly by fossil fuels and hydropower. These options have benefited from government subsidies and are widely available on world markets. However, these conventional energy systems are often out of reach for people in remote areas, and even in urban slums, they are sometimes too expensive for the poorest to afford.

In addition, in many developing countries, most of the fuel and many of the technologies are imported. Of the 47 poorest countries, 38 are net importers of oil, and 25 import all of their oil.

The economic risk of relying primarily on imported energy has grown in recent years as oil prices have become less stable, doubling in less than two years to over $60 per barrel.[4] These rising prices have had a disproportionate impact on poor people who depend on kerosene and liquefied petroleum gas (LPG) for their basic cooking and heating. In many poor countries, governments subsidize basic fuels such as kerosene, and the cost of these subsidies has skyrocketed in the past two years—reducing the funds available to governments to pay for education, health care, clean water, and other public investments that are essential for meeting the MDGs.

The rapid recent growth in solar, wind, geothermal, and biomass energy, coupled with ongoing technology improvements and cost reductions, is making a growing array of renewable energy options available to help achieve the MDGs. Although the strongest renewable energy growth has been in grid-connected power systems and liquid fuels for transportation, several renewable energy technologies are well-suited to providing modern energy services for low-income people. Scaling up a broad portfolio of renewable energy options can make a major contribution to achieving the MDGs.

Modern renewable energy technologies turn widely available but intermittent resources into usable forms of thermal, chemical, mechanical, and electrical energy. Among the renewable energy options that are currently in wide use in some regions and are now ready for large scale introduction in many areas of the developing world:

- Biogas for decentralized cooking and electricity
- Small Hydro Power for local electricity

[†]The primary focus of this paper is "new" renewable energy sources. Large hydro power, which is a well-established energy source in many developing countries, is discussed only in passing. For a full discussion of the advantages and disadvantages of expanded use of large hydro power, see the World Commission on Dams report, *Dams and Development* (London: Earthscan, 2000).

- Small Wind Power for water pumping and local electricity
- Solar Photovoltaics for local electricity
- Solar Collectors for water and space heating
- Ethanol and Biodiesel for agriculture and transportation
- Large Hydro Power for grid electricity
- Large Wind Power for grid electricity
- Geothermal Energy for heat and grid electricity

Renewable energy projects developed in scores of developing countries–many with international donor assistance–have demonstrated that renewable energy can contribute to poverty alleviation directly by providing the energy needed for creating businesses and jobs, turning locally available resources into productive economic assets.

Renewable energy technologies can also make indirect contributions to alleviating poverty by providing energy for cooking and space heating. Improved biomass stoves and liquid and gaseous fuels derived from locally produced biomass can reduce the drain on household income, while freeing up time for education and income-generating activities. By making light more affordable and reliable, renewable energy technologies also permit schools and businesses to operate after dark.

Renewable energy can contribute to education as well, by providing electricity to schools, improving attendance, retaining teachers, and powering educational media. Renewable energy for cooking and heating can reduce the time that children, especially girls, spend out of school collecting fuel. In addition, the displacement of traditional fuels reduces the health problems from indoor air pollution produced by burning those fuels. Renewable energy can also contribute to improved health by providing energy to refrigerate medicine, sterilize medical equipment, and incinerate medical waste. And it can provide power for supplying the fresh water and sewer services needed to reduce the burden of infectious disease.

By developing energy sources such as large hydro power, wind power, geothermal power, and liquid biofuels, developing countries can reduce their dependence on oil and natural gas, creating energy portfolios that are less vulnerable to price fluctuations. In many circumstances, these investments can be economically justified as less expensive than a narrower, fossil fuel-dominated energy system.

Most poor countries have abundant renewable resources, including varying combinations of solar, wind, geothermal, and biomass, as well as the ability to manufacture the relatively labor-intensive systems that harness these. However, only a few developing countries have adopted the policies needed to spur the development of renewable energy technologies and markets, which have been dominated by Europe, Japan, and North America. The exceptions include Brazil, which has built the world's leading biofuels industry, and China and India, which are leaders in developing decentralized renewable sources such as small hydro, small wind, biogas, and solar water heating.

Renewable energy technologies face a number of barriers that have delayed scaling-up their production and use in developing countries. Unlike conventional energy sources, which have benefited from decades of research and development, an established industrial base, and government-subsidized infrastructure support, renewable energy options are just becoming known in many regions. Government policies and support systems are frequently biased in favor of conventional energy sources. New policies can have a dramatic impact on the pace of introduction of renewable energy, as several developing countries have demonstrated.

Most renewable energy sources require a significant up front investment, as has been the case for most of the conventional energy sources that dominate today's energy system. This means that in the early years of deployment, renewable energy options are typically more expensive than the conventional alternative. Government intervention to level the playing field is therefore needed to start the development process. Experience shows that as the scale of use increases, costs decline significantly in the early years.

A growing number of developing country governments have recognized the essential role that renewable energy technologies can play in meeting basic energy needs and achieving the MDGs. Well-designed policies will allow the cost of the renewable options to fall rapidly in the first several years. It is through the combined efforts of governments and the private sector that strong, sustained markets for renewable energy are most likely to develop. Experience in recent years suggests that the following actions can play a crucial role in scaling up the use of renewable energy:

- Create Supportive Policy and Institutional Frameworks
- Promote Private Sector Involvement
- Level the Playing Field
- Nurture Micro-Enterprise
- Build Projects Around Local Needs and Capacities

Biogas cooking from cow dung in India

1. ENERGY FOR DEVELOPMENT

Providing modern energy services is crucial for the eradication of extreme poverty as called for in the United Nations Millennium Development Goals (MDGs), according to a study commissioned for the Millennium Project Task Force 1 on Poverty. This requires the deployment of energy technologies as quickly and cost-effectively as possible. While the importance of expanded modern energy access to achievement of the MDGs has yet to receive sufficient attention, it has been explored in a number of recent publications written in parallel to the Millennium Project Report. The energy demands to address MDGs are, for the most part, technologically neutral—that is, what is most critical is the access to reliable and affordable energy, not the actual source of that energy.[5]

To better understand the role of energy in human development, the International Energy Agency (IEA) recently developed the Energy Development Index, which measures a country's progress in its transition to modern fuels as well as the degree of maturity of its energy end-use.[6] After incorporating energy into the production function, IEA studies point to energy use as a contributing factor in development, rather than simply an outcome.[7]

Although energy use and economic growth are decoupled at higher levels of development, for the world's poorest people, small increases in energy consumption are often associated with dramatic improvements in quality of life. Energy consumption correlates closely with both welfare and economic growth.[8] At the local level, modern energy services help to reduce drudgery of women's labor, improve health and education, and stimulate micro-enterprises. At the national level, energy services facilitate economic development by underpinning industrial growth and providing access to global markets and trade.[9]

Energy choices have broad macroeconomic effects as well, influencing the ability of governments to meet the immediate needs of their poorer citizens. During a time of high and unstable oil prices, the impact of energy import-dependence on low-income countries and on poor households is of increasing concern. Although a handful of low-income countries are net exporters of oil, the majority are not, and many suffer from energy-import bills that represent significant percentages of both GDP and total export earnings.[10] Thus, a competitive and diversified energy portfolio is vital to the development of domestic industry and employment, national economic health, and the availability of public funding to achieve the MDGs.

UNDERSTANDING ENERGY POVERTY

Energy consumption and efficiency vary dramatically in different parts of the world. In 2005, average annual per-capita consumption of modern energy (i.e., excluding traditional biomass and waste) is 1,519 kilograms of oil equivalent (kgoe). While the average in high-income countries is 5,228 kgoe, in low-income countries it is only 250 kgoe. Traditional biomass and waste account for 10.6 percent of total global primary energy supply. In low-income countries, these sources represent on average 49.4 percent of the supply, with some countries approaching 90 percent.[11]

For the world's poor, the only source of energy that is generally available and affordable is "traditional biomass," including fuel wood, crop residues, and animal wastes. Often, the poorest segment of the population lacks access even to these primitive fuels. Without modern energy, opportunities for economic development and improved living standards are constrained. Women and children in developing countries suffer disproportionately, as they spend much of their time gathering wood.[12] In heavily populated or resource-poor areas, this practice can deplete forests and soils.[13]

Burning traditional biomass over open fires or in inefficient stoves contributes to health-threatening indoor air pollution. As many as 2 million deaths each year are attributed to this risk factor.[14] The World Health Organization estimates that 1.6 million of these deaths are women and children, whose responsibility for domestic chores makes them relatively more exposed to indoor air pollution from cooking and heating.[15] Although the IEA projects that the share of commercial energy will rise from 80 percent in 2002 to 84 percent in 2015, the number of people relying on traditional fuels for cooking and heating will also continue to grow, from 2.4 billion in 2002 to over 2.6 billion in 2030.[16]

Roughly 1.6 billion people worldwide do not have access to electricity in their homes, representing slightly more than one-quarter of the world population. This lack of electricity deprives people of basic necessities such as refrigeration, lighting, and communications. Most of the electricity-deprived live in South Asia and sub-Saharan Africa. Although the total number of people without electricity has fallen by around 500 million since 1990, rapid electrification in China accounts for most of this progress. Excluding China, the number of people lacking electricity has in fact increased over the past three decades.[17]

Of the 1.3 billion people worldwide living on less than $1 per day, around 800 million reside in rural areas and 500 million live in urban shantytowns.[18] Currently, four out of five people without electricity live in rural areas of the developing world.[19] However, by 2017, the number of urban dwellers is expected to equal the number of rural dwellers in the less developed regions.[20] The pressure on cities from rural-to-urban migration increasingly diminishes the differences between rural and urban energy poverty. Many of the urban poor are recent migrants that continue to rely on traditional fuels for cooking and heating and on dim kerosene lamps for lighting. They are commonly unable to shift to higher-quality lighting because the power utility does not serve their neighborhood. They may sit on a waiting list for several years before obtaining LPG with which to cook.[21]

THE ROLE OF ENERGY IN ACHIEVING THE MDGS

Adopted by the international community in 2000, the United Nations Millennium Development Goals outline specific development objectives to be achieved by 2015, including halving the proportion of the world's people living on less than $1 a day. Although energy is not explicitly mentioned in any of the MDGs, there is a growing recognition that energy services play a crucial role in development efforts and in the improvement of living conditions around the world.

The following matrix, adapted from the UK Department for International Development's 2002 report "Energy for the Poor: Underpinning the Millennium Development Goals," lays out the direct and indirect links between energy and the MDGs:[22]

A sugarcane field in Uganda

TABLE 1: Importance of Energy to Achieving Specific Millennium Development Goals

MDG	Steps Toward Goal	Modern Energy Contributes by
1. Cutting Extreme Poverty and Hunger	• Reduce by half the proportion of people living on less than $1 a day • Reduce by half the proportion of people who suffer from hunger	• Reducing share of household income spent on cooking, lighting, and space heating. • Improving ability to cook staple foods. • Reducing post-harvest losses through better preservation. • Enabling irrigation to increase food production and access to nutrition. • Enabling enterprise development, utilizing locally available resources, and creating jobs. • Generating light to permit income generation beyond daylight. • Powering machinery to increase productivity.
2. Universal Primary Education	• Ensure that all boys and girls complete a full course of primary schooling	• Providing light for reading or studying beyond daylight. • Creating a more child-friendly environment (access to clean water, sanitation, lighting, and space heating/cooling), which can improve attendance in school and reduce drop-out rates. • Providing lighting in schools, which can help retain teachers. • Enabling access to media and communications that increase educational opportunities. • Reducing space heating/cooling costs and thus school fees.
3. Gender Equality and Women's Empowerment	• Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015	• Freeing women's time from survival activities, allowing opportunities for income generation. • Reducing exposure to indoor air pollution and improving health. • Lighting streets to improve women's safety. • Providing lighting for home study and the possibility of holding evening classes.
4, 5, 6. Health	• Reduce by two-thirds the mortality rate among children under five • Reduce by three-quarters the maternal mortality ratio • Halt and begin to reverse the spread of HIV/AIDS • Halt and begin to reverse the incidence of malaria and other major diseases	• Providing access to better medical facilities for maternal care. • Allowing for medicine refrigeration, equipment sterilization, and safe disposal by incineration. • Facilitating development, manufacture, and distribution of drugs. • Providing access to health education media. • Reducing exposure to indoor air pollution and improving health. • Enabling access to the latest medicines/expertise through renewable-energy based telemedicine systems.
7. Environmental Sustainability	• Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources • Reduce by half the proportion of people without sustainable access to safe drinking water • Achieve significant improvement in the lives of at least 100 million slum dwellers, by 2020	• Boosting agricultural productivity, increasing quality instead of quantity of cultivated land. • Reducing deforestation for traditional fuels, reducing erosion and desertification. • Reducing greenhouse gas emissions. • Restoring ecosystem integrity through land management.

Energy is one of several essential inputs to economic and social development. In 2004, an attempt was made at a U.N. Millennium Project workshop to envision steps in the energy area that each country could take by 2014. These include:

- Enabling the use of modern fuels for 50 percent of those who currently use traditional biomass for cooking.
- Supporting efforts to develop and adopt improved cook-stoves, means to reduce indoor air pollution, and measures to increase sustainable biomass production.
- Enabling access to reliable modern energy services for all urban and peri-urban poor.
- Providing electricity (for such services as lighting, refrigeration, ICT, water pumping and/or purification) for all schools, clinics, hospitals, and community centers.
- Enabling access to mechanical power for all communities.
- Providing all-weather-vehicle accessible roads and access to motorized transport for all communities.[23]

"Modern" energy services—provided by liquid and gaseous fuels as well as electricity—can greatly assist societies in reducing poverty and hunger and meeting the health, education, gender, and environmental elements of the Millennium Development Goals. Studies show that the share of overall energy use provided by modern fuels and electricity is strongly correlated with per-capita income, life expectancy, literacy, and other indicators of human development.[24] International Energy Agency analysis suggests that if the MDG poverty-reduction target is to be met, governments will need to take new measures to extend the use of modern fuels to more than 700 million people from 2002 to 2015 and to provide electricity to the remaining half-billion people projected to still lack it.[25]

It is estimated that the minimum amount of modern energy needed annually to meet basic cooking and lighting needs is 50 kgoe per capita. However, societies also need to educate children, ensure good health and access to clean water, and provide energy for various productive uses. It is therefore estimated that societies require 400 kgoe of energy per capita to fall safely above the energy poverty line. "Energy Services for the Poor," commissioned for the Millennium Task Force on Poverty, calculates that achieving an increase in per-capita modern energy consumption in developing countries from 50 kgoe to 500 kgoe will lead to a 50-percent reduction in the number of people living in poverty. The authors predict that total annual public funding needed to meet these targets by 2015 is \$14.3 billion total, or \$20 per capita.[26]

Wind pump outside Colesberg, Africa

2. RENEWABLE ENERGY'S POTENTIAL CONTRIBUTION TO ACHIEVING THE MDGS

Development efforts over the past 50 years have been hampered by the difficulty of providing modern, commercial energy to the poor. The relatively high cost of modern fuels and electricity for the poor, particularly in dispersed rural areas, has severely limited the ability to reach those most in need. In Kenya, for example, the average cost of a new connection for rural homes is seven times the national per-capita income.[27] The cost of obtaining energy for the poor is more than the cost of electricity for higher-income groups. In the Philippines, for example, the lowest-income fifth of the population pays $1.79 per kgoe of energy, while the top fifth pays $0.66 per kgoe.[28] The poor lack cash to buy fuels in large quantities. They also must rely on thermally inefficient stoves or open fires to obtain their energy, which introduces additional loss.[29]

The volatile and unpredictable price of fossil fuels has further exacerbated the problem of insufficient energy development. By causing large budget and trade deficits, fossil fuels have also undermined the ability of developing country governments to meet the needs for basic services such as education, health care, and clean water.[30]

Meanwhile, renewable energy technologies (RETs) have advanced quickly in recent years, and as their cost has declined and their reliability has improved, they have emerged in some circumstances as a more affordable and practical means of providing essential energy services.[31] Renewable energy sources capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. RETs are the technologies that harness these energy flows and turn them into energy services to meet the needs of individuals for heat, light, power, transport, and electrical energy. (See Table 2, page 13)[32]

The appropriateness of energy technologies depends on the service being met and on the context of need. Grid-connected renewable energy is contributing a growing share of power generation, as 14 developing countries now have some type of policy to promote renewable power generation.[33] Off-grid renewable energy-based systems make an important contribution in providing energy to rural and sometimes urban areas unlikely to be served by the national grid in the medium- to long-term.[34]


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Women carry firewood in Kenya

TABLE 2: Major Renewable Energy Technologies and Applications, 2005[35]

Renewable Energy Technology/Application	Energy Service	Locale of Application
Solar PV	Residential and industrial electricity (grid-connected)	Mostly urban
Solar Home Systems (SHS)	Lighting (homes, schools, streets) and other low-to-medium voltage electric needs (telecommunications, hand tools, etc.)	Urban and rural
Solar PV Pumps	Pumping water (for agriculture and drinking)	Mostly rural
Solar Thermal	Residential and industrial electricity (grid-connected)	Mostly urban
Solar Water Heaters	Heating water	Urban and rural
Solar Cookers	Cooking (for homes, commercial stoves, and ovens)	Mostly rural
Solar Dryers	Drying crops	Mostly rural
Wind Turbines	Residential and industrial electricity (grid-connected), Mechanical power and low voltage electricity needs (small stand-alone)	Urban and rural
Wind Pumps	Pumping water (for agriculture and drinking)	Mostly rural
Biogas	Residential and industrial electricity (grid-connected), cooking and lighting (household-scale digesters), motive power for small industry and electric needs (with gas engine)	Urban and rural
Solid Biomass	Cooking and lighting (direct combustion), motive power for small industry and electric needs (with electric motor)	Mostly rural
Liquid Biofuel	Transport fuel and mechanical power, particularly for agriculture; heating and electricity generation; some rural cooking fuel	Urban and rural
Large Hydro	Grid electricity (residential and industrial)	Mostly urban
Small Hydro	Lighting and other low-to-medium voltage electric needs (telecommunications, hand tools, etc.), process motive power for small industry (with electric motor)	Mostly rural
Geothermal	Grid electricity and large-scale heating.	Urban and rural
Village-scale Mini-grids and Solar/Wind Hybrid Systems	Lighting (homes, schools, streets) and other low-to-medium voltage electric needs (telecommunications, hand tools, vaccine storage, etc.)	Mostly rural, some peri-urban

As Table 2 demonstrates, renewable energy technologies meet a wide range of energy needs, though their suitability and economic feasibility vary widely within and between countries. The development community is already using several RETs, including small-scale biogas, hydro, wind, and solar, extensively to meet the needs of rural areas of the developing world, particularly in South Asia and sub-Saharan Africa.[36]

In other cases, developing countries are deploying advanced, large-scale renewables, including large-hydro, geothermal, wind power, and biofuels, in much the way these technologies are used in industrial nations.[37] Although these grid-connected energy sources primarily meet the needs of the urban middle class,[38] by reducing overall dependence on fossil fuels they may improve general economic conditions and thus help in achieving the Millennium Development Goals.

The rise of RETs is being driven by technological advances, economies of scale in production, declining costs, and rapidly growing political support.[39] Over the past five years, annual installations of wind farms have doubled, while annual installations of solar power systems have increased six-fold.[40] Total installed capacities of both technologies have grown at an average annual rate of 20–30 percent over the past decade, closer to the high growth rates seen in computers and mobile phones than to the single-digit growth rates common in today's fossil-fuel markets. While the costs of on-shore wind turbines have declined by 12–18 percent with each doubling of global capacity, the costs of solar PV have declined by 20 percent per doubling. Although costs of solar PV rose in 2004 due to market factors, further cost reductions in both technologies are expected due to efficiency and scale.[41]

The market for solar thermal collectors, which capture the sun's warmth to heat water and building space, grew some 50 percent between 2001 and 2004. About 18 million square meters of capacity were added in 2004, mostly in China, bringing the energy equivalent of global installations to a level far exceeding that of global wind and solar power combined.[42] Meanwhile, costs have fallen from about 44 cents/kWh in the 1980s to 12–18 cents/kWh today, with future cost reductions expected due to efficiency and scale.[43]

Production and use of biofuels also advanced quickly in 2004, spurred by agricultural, environmental, and consumer interests. Fuel ethanol production increased 13.6 percent, reaching almost 33 billion liters. Nearly twice as much ethanol was produced in 2004 as in 2000. Ethanol is by far the most widely used biofuel for transportation, and Brazil and the United States dominate the market. World production of biodiesel fuel, based on vegetable oil and fats, is smaller but has been growing even faster to nearly 1.8 billion liters in 2003, up 18 percent over 2002.[44]

Worldwide, at least 45 countries have policy targets for renewable energy. Ten of these have been introduced by developing countries, including Brazil, China, Dominican Republic, Egypt, India, Korea, Malaysia, Mali, South Africa, and Thailand.[45] Generation of small hydropower, biomass power, and geothermal power in developing countries each account for more than half of total global generation.[46]

Although most solar and wind-power capacity is in industrial countries, these are global technologies and many developing countries are moving rapidly into the industry. Both India and China have developed substantial domestic manufacturing of wind turbines and solar PV modules.[47] The Philippines emerged as a solar PV manufacturer as well, and Thailand will soon follow suit.[48]

In addition to their environmental sustainability and low- to non-existent emissions, RETs create new economic opportunities and can be locally produced. While grid-connected RETs can have a larger impact on national energy portfolios and the macroeconomic health of a country, decentralized off-grid RETs increasingly contribute to community-level energy development, particularly in rural areas, and should be recognized for their potential contribution to achieving the MDGs.

A substantial portion of the world's poor lives in areas where the cost of extending the grid is often prohibitive due to isolating terrain or remoteness. According to a World Bank study of several developing countries, grid extension to rural areas typically ranges from $8,000–$10,000 per kilometer, not including the cost of materials, which adds an additional $7,000. This high cost, coupled with very low capacity utilization of such grids due to very small loads, makes extension economically unviable to utilities.[49] Decentralized RETs such as solar photovoltaics (PV), biogas digesters, biomass gasifiers, biofuels, small wind-electric turbines, and micro-hydro systems are often a more affordable way to extend energy services.

Around 16 million rural households light their homes from biogas produced in small-scale anaerobic digesters. This includes 12 million households in China and 3.7 million in India. In Nepal, the Biogas Support Programme, a Clean Development Mechanism (CDM) project under the Kyoto Protocol, proposes to supply 200,000 new biogas plants by 2009. Currently, around 20,000 new systems are being installed there each year.[50]

Worldwide, small hydropower (SHP) produces 61 gigawatts (GW) of power, with over half of that capacity installed in developing countries. Tens of millions of rural homes receive power from small hydro, mostly in China.[51]

The market for small home and farm wind-energy systems has seen remarkable growth over the past 15 years. Small wind companies have set ambitious growth targets continuing at 18–21percent over the next five years. American Wind Energy Association analysis shows that average small wind turbine costs have decreased by 7 percent over the past 5 years, from $2250/kW to $2,100/kW, and manufacturers are aiming to reduce costs another 20 percent to $1,700/kW by 2010.[52]

Despite these impressive trends, the perceived "high cost" of RETs limits both public and private investment in grid-connected as well as off-grid RETs. There are a number of reasons for this perception. Conventional energy systems with their policy framework and public financing advantages are characterized by low capital costs, but have significant operating costs. The high capital costs of installing renewable energy systems are often inappropriately compared to the capital costs of conventional energy technologies. Over time, the low operating costs of renewable energy systems offset their high capital costs through avoided fuel expenses, but this kind of life-cycle accounting is not regularly used as a basis for comparison. In addition, the externalities associated with energy systems—particularly the environmental costs associated with conventional energy systems—are often not fully accounted.[53]

RETs provide a number of benefits such as increased employment, reduced import dependence, and reduced burden on foreign exchange. However, the marketplace does not account for this value creation.[54] Meanwhile, government subsidies for conventional energies now exceed $200 billion annually, making it very difficult for renewable energy to achieve economies of scale.[55] A Global Environment Facility report notes public-sector support often distorts markets, as "early donor-driven RET projects focused on installing a targeted number of systems without regard for commercial sustainability or replication."[56] In reaction to this trend, an investment-centered approach evolved during the 1990s for models to catalyze private-sector energy delivery in rural areas.[57]

"Because the ability of the rural poor to pay is low and because long-term, off-grid service costs are not known, market entry in rural off-grid markets was, and is still, considered a high-risk, low-return proposition. Financing rural renewable energy is particularly daunting, as credit is often unavailable and transaction costs are high, and demand is highly dispersed. The up-front costs of equipment and installation, not to mention ongoing maintenance costs, are not affordable for many rural residents without long-term financing options, while banks and other financial institutions are often reluctant to lend to consumers and entrepreneurs for RET systems."[58] These situations are similar to the conditions found in Germany and Japan before strong government leadership helped address the barriers to entry.[59]

As a result, the investment vehicles developed were often supplied with large grant subsidies to help compensate for the small size of transactions and the complexities of new systems. It was expected that companies would emerge based on the financial rewards of revenue flows from rural customers if equity and debt financing for the rural poor was made available.[60]

Today, however, development experts find it unlikely that dependence on prompting private-sector involvement will have much effect on the delivery of rural energy services to the poor.[61] Even when RETs are least-cost on a life-cycle basis, like all modern energy sources, they are often not affordable or able to be scaled-up without the support of governments. The provision of energy through conventional technologies is a public service. Even the most advanced, large-scale, fossil-fuel-based urban energy development projects depend on the financial support of governments and benefit from regulatory frameworks and taxation schemes that often use public resources to offset private risk.[62]

The Millennium Task Force on Poverty estimates that total public funding required to achieve the necessary energy targets (summarized on page 11) will amount to $14.3 billion annually, or $20 per capita.[63] To put this figure in perspective, current annual investments in energy-related infrastructure are estimated at $200–250 billion,[64] and the IEA has projected that infrastructure investment between 2001 and 2030 will approach $16 trillion.[65] Nearly all of this investment goes to conventional energy sources. Moreover, these figures do not include estimates of the costs associated with fossil fuels in terms of either local pollution or impact on the global climate. In fact, people (mostly poor) in the developing world currently spend about $20 billion per year to get energy from distributed conventional sources such as batteries, kerosene lamps, and candles.[66]

"Instead of withdrawing to let private markets develop on their own, development agencies that recognize the potential contribution of RETs are redirecting their efforts to remove barriers and reduce risk in renewable energy markets."[67] A very small shift in the direction of government support and subsidies, from conventional forms of energy toward RETs that harness sustainable resources, would provide significant and immediate impetus toward meeting the MDGs.

RETs can help diversify a country's energy portfolio and reduce the risk of over-dependence on fossil fuels, risks that fall disproportionately on the poor[68] and that undermine efforts to meet the MDGs. Not only are RETs a hedge against future price increases in conventional fuels, but they improve the balance of trade and create new economic opportunities.[69]

Rising energy prices have a greater impact on poor countries than on richer ones. Of the 47 countries with per-capita incomes of less than $2 per day, 38 are net importers of oil, while 25 import all of their oil. Imported energy provides 81 percent of total supply in the Dominican Republic and 93 percent in Morocco (versus 50 percent in Japan and 27 percent in the United States).[70] According to the World Bank, the $20 per-barrel oil price increase of the past two years can be expected to reduce the GDPs of the poorest countries by up to 3 percent.[71]

Net oil importers, the group of countries with the lowest per-capita income, suffer the largest proportional loss in GDP, as do the rural poor and small enterprises in general, due to the prevalence of kerosene. If governments pass on higher costs through oil product prices, the poor suffer disproportionately.[72] It was found that a $15-per-barrel price increase of petroleum products raised the cost of acquiring the same bundle of goods by 14 percent for the lower income population in comparison to 7 percent for the upper income population.[73] But even if the government does control prices, the poor still suffer disproportionately. The growing financial burden of energy subsidies can force governments to cut other items from the budget. Because government spending is usually dominated by social commitments such as education and health care, weakened national treasuries tends to reduce investment in human development.

In 2004, the governments of Thailand and Malaysia each spent more than $1.2 billion subsidizing fossil fuels, and oil prices have increase significantly since then. In Indonesia, the government spent $6.4 billion on subsidies for conventional fuels in 2004; efforts to raise fuel prices in 2005 led to large protests in the streets of Jakarta.[74] It is now reported that Indonesia is expected to spend almost $14 billion—or a third of central government expenditures—on fuel subsidies this year.[75]

There is growing recognition that RETs can be a good investment, contributing to economic growth and poverty alleviation at the local level. The following sections assess the potential of renewable energy to contribute to each of the individual MDGs. Where possible, the case studies used to illustrate the potential contribution of RETs were selected for their potential for wide dissemination. However, most of these are donor-driven pilot projects, reflecting the fact that there are few self-sustaining renewable energy markets in place in poor countries today.

MDG 1: POVERTY AND HUNGER

Target: To halve the number of people who suffer from hunger and whose income is less than $1 a day.

RETs Can Supply Cooking and Heating Fuel, Saving Time and Income

Around 80 percent of the expenditure on energy services by poor people is on fuel for cooking.[76] Studies show that the majority of the developing world's poor spend 20 percent or more of their monthly income to obtain wood and charcoal.[77] And this 20 percent figure is biased downward because it does not reflect the opportunity cost of labor time dedicated to fuel wood collection or the health costs of indoor air pollution. The recent UN-Energy report estimates that people spend up to five hours per day gathering fuelwood in sub-Saharan Africa. In most of the cases, the girl child is most affected, as it is her responsibility to travel long distances and collect the fuel wood.[78]

By providing sustainable energy for cooking and space heating at low operating costs, improved stoves and alternative fuels can reduce this drain on household income, while freeing up time for education and income-generating activities.

Around 16 million rural households cook and light their homes using biogas produced in household-scale anaerobic digesters. This includes 12 million households in China (see case study below) and 3.7 million households in India. In Nepal, the Biogas Support Programme, a Clean Development Mechanism project under the Kyoto Protocol, proposes to supply 200,000 new biogas plants by 2009. Currently, around 20,000 new systems are being installed there each year.[79]

A typical digester of 6–8 cubic meters in size produces 300 cubic meters of biogas a year and, if manufactured domestically, costs $200–250 and pays for itself over time. These units can be supplied by local companies, as digesters are a simple technology with no need for advanced expertise. After receiving training, farmers can build the digesters themselves. A new government program in China, started in 2002, subsidizes farmers who build their own units, providing nearly $100 per digester. Estimates suggest that more than 1 million biogas digesters are being produced in China each year.[80]

Biogas has advantages over other technologies because it has the added benefit of producing a soil amendment that can boost agriculture productivity. Moreover, in addition to providing energy for cooking and heating, the systems can be potentially combined with a generator that produces electricity and motive power.[81]

Case Study: Biogas Digesters in China[82]

In 2003, approximately 1 million households in China had biogas digesters, and between 2003 and 2005, some 11 million additional rural families reportedly began using them. As the digesters are powered with livestock or domestic waste, generally speaking, a family with one head of cattle or three pigs is able to supply a digester.

Lianshui County, just east of Xu Huai plateau, is an under-developed county whose economic structure is based on agriculture. In 2001, 3,600 biogas digesters were installed in six villages, and in 2003 hundreds of families in these villages were surveyed to evaluate the impact of the project. According to the survey, families in the county primarily use energy for cooking (62 percent) and for heating water and raising animals (25 percent). Per-capita energy consumption in families possessing biogas digesters is 337 kgce due to higher heat efficiency, while those without them use 451 kgce. Consumption of stalk and straw in these families is 168 kgce and 322 kgce, respectively.

Biogas mainly substitutes stalk and straw and a small amount of firewood, and does not substantially substitute LPG, which in the countryside is used only by a few families with high incomes. With incomes in Lianshui County comparatively low and the price of LPG high, places to buy or recharge the fuel are limited and most people are not willing to spend the money. While families without biogas digesters mainly use straw and stalk as fuel, families with biogas digesters can reuse straw and stalk in their fields as organic fertilizer. Statistics also show that families with biogas digesters spend near 100 yuan (US$12) less than those without them. Of families surveyed, 74 percent find it convenient to use biogas, and nearly half of the families without a digester have decided to build one.

Biofuel can also be produced locally to replace conventional fuels and traditional biomass used for cooking. In a survey of six developing countries (Ethiopia, Malawi, Mozambique, Senegal, South Africa, and Zimbabwe), using the ethanol-based product "Millennium Gelfuel" was found to be cheaper than cooking with an LPG burner or kerosene in five out of six countries, and was cost competitive with charcoal in Zimbabwe and South Africa. (See case study below.) Gelfuel is a compound of ethanol and a small amount of cellulose. With the addition of water a clear and transparent gel is formed that is safer than kerosene and other liquid fuels. The scale-up of ethanol production in developing countries holds potential for economic growth in rural areas, ecosystem rehabilitation, and the reduction of fossil-fuel import expenditures.

Case Study: Biofuel Use in Africa[83]

Between 2000 and 2003, the World Bank's Development Marketplace Program shepherded the Millennium Gelfuel Initiative (MGI), a public-private partnership aimed at adapting and disseminating an existing ethanol-based cooking fuel, known as gelfuel, for African households. Gelfuel is based on ethanol produced through the fermentation and distillation of sugars (derived from molasses, sugar cane, sweet sorghum, etc.) or starch crops (cassava, maize, etc.). It is renewable and can be produced locally in most African countries.

A 2003 study found that improvements in combustion, end-use efficiency, and production had resulted in a more than 50-percent reduction in the cost of gelfuel. Private gelfuel plants now operate in South Africa (with a production capacity of 200,000 liters/month), Zimbabwe (20,000 liters/month), and Malawi (25,000 liters/month). Projects are under different stages of preparation in Benin, Ethiopia, Madagascar, Mozambique, and Senegal.

Direct ethanol itself costs only about 70 percent as much as gelfuel, but until recently was not considered appropriate for cooking due mainly to incompatibility with stoves and the potential for spillage. With the recent development of new low-cost (US $15) direct-ethanol stoves, cooking with biofuel will lower the expense of cooking even more, making direct ethanol competitive even with fuel wood and charcoal.

Approximately 1 million households worldwide possess solar cookers, most of them in China and India.[84] One of the main problems with this technology, however, is that it requires households to adapt to a new way of cooking that is often quite different from traditional methods. Cooking periods are longer, the food tastes different, and the process takes place outside of the house.[85] In addition, the solar cooking system must be complemented with an alternative that can be used on cloudy days, in cases of urgency, or during the night. Solar cookers typically meet only 30–70 percent of basic cooking requirements, primarily for the mid-day meal.[86]

Nonetheless, experiences with stoves in solar-rich areas illustrate the advantage of solar cooking over fuel wood consumption in terms of reduced time devoted to wood gathering and the improved health of consumers.[87]

Kerosene and liquefied petroleum gas (LPG) play a growing role in off-grid energy supply. In cities and peri-urban areas, modern fuels such as kerosene and LPG are often widely marketed via well-established distribution networks. And the fact that these fuels are widely used in cities makes it relatively easy to extend their distribution into rural areas. Rapid fuel-switching away from wood has been achieved through government policies that subsidize and otherwise promote the use of kerosene and LPG. In India, for example, the government has utilized a public distribution system for promoting the sale of kerosene, making it available to the poor at ration shops at subsidized prices.[88]

Poor consumers' access to kerosene and LPG is still limited by supply and distribution restrictions. In addition, the economics of kerosene and LPG are now clouded by the dramatic increases in fuel prices since 2003. Large and growing subsidies are required to make these fossil fuels affordable for low-income citizens.[89] Governments and development agencies would be wise to simultaneously invest in the commercialization of RETs, particularly biofuels, which have the potential to be locally produced and which can utilize portions of the very distribution networks that are now used to distribute kerosene and LPG. In Mali, for example, oil from the seeds of Jatropha bushes can be used for cooking, lighting, and running engines (See Mali case study, p. 28.) The development of renewable fuels for cooking should be given more attention, as it is one of the most urgent and widespread energy needs for the poor.

RETs Can Provide Lighting, Communications, Refrigeration, and Conveniences

Electricity is an essential input to lighting, refrigeration, and communications and is necessary for the development of small- and medium-sized enterprises, educational institutions, health clinics, and water supply systems. "Electricity can contribute directly to poverty reduction by amplifying human capacity, that is, by making it possible to engage in commercial activity and reducing unit costs. Indirect contributions to poverty alleviation may come in the form of free time for other productive activities, improved health and education, improved access to and supply of clean water, and reduced local environmental degradation."[90]

The 1.6 billion people who do not yet have reliable electricity include most of the world's poor. Not only is a large majority of the poor population unable to access modern energy services, but as already discussed they also pay dearly for the significantly lower-quality services that are available.[91] For example, batteries, when available, must be transported frequently to charging stations, are often of low quality, and are used while improperly charged, thus incurring high costs per unit of electricity.[92]

Equipment that requires continuous operation for long periods of time is often incompatible with affordable use of generators, the costs of which are directly related to the duration of operation. Most small domestic appliances, meanwhile, have power requirements far below the scale at which generators can be cost-effective.

In contrast, RETs such as solar photovoltaics (PV), biogas digesters, small wind-electric turbines, and micro-hydro systems are often ideal for providing electricity in rural areas, ranging from a few watts to thousands of watts, at a lower life-cycle cost than conventional alternatives such as dry cell batteries and generator sets. RETs can reduce the share of household income spent on lighting by replacing more-expensive conventional fuels. By making light more affordable and reliable, RETs also permit income generation beyond daylight.

A recent ESMAP study estimates the total benefit of providing domestic electricity to a typical, non-electrified Filipino household at $81–150 per month, mainly from time saved collecting fuel and improved productivity of home businesses. Other studies point to a positive relationship between electricity and educational opportunities, as well as higher earnings and public safety.[93]

Solar home systems (SHS) may be used for running lights, televisions, and radios for a few hours every day, usually replacing kerosene or candles. More than 200,000 such systems were installed worldwide in 2004 alone—primarily in Bangladesh, Brazil, China, India, Kenya, Sri Lanka, and Thailand—adding to the global installed base of 1.9 million units at the end of 2004. The commercial sale of PV in Kenya, without explicit development assistance, is an example of successful large-scale dissemination.[94] Thailand started an ambitious program of SHS dissemination in 2004. The objective is to install 300,000 systems by the end of 2005, and it is estimated that at the end of 2004, 100,000 had been installed.[95]

However, the record of rural solar programs is mixed, as most poor rural households can't afford even the low-end solar systems.[96] As a result, ambitious targets for wide deployment of SHS are often under-reached, reflecting the challenge of working in poor rural areas while having expectations of meeting conventionally defined commercial terms.

Household wind turbines have been applied by scattered rural dwellers and isolated rural communities, mostly for domestic uses and the supply of basic services, though these can also be used to power medium-voltage appliances. Wind power thus represents a significant technology to meet certain minimum non-caloric household and production needs at lower cost per power unit than photovoltaic systems.[97]

Case Study: Wind Energy in Eritrea[98]

More than 95 percent of Eritrea's rural population and 20 percent of urban residents currently lack access to electricity. To address this problem, the Global Environment Facility (GEF) formulated and funded a pilot project to demonstrate the potential for wind-generated energy in the country. The project resulted from a thorough assessment of the wind potential in Eritrea, jointly funded by the United Nations Development Programme and the GEF. In addition to a small 750-kilowatt wind park, eight small-scale decentralized wind stand-alone and wind-diesel hybrid systems will be installed to provide lighting in wind-rich rural villages.

The potential for replicating small-scale wind stand-alone and hybrid systems in Eritrea's south and highlands is a factor of around 30–40, related to the number of demonstration projects. In other words, in addition to the eight pilot villages/production sites, approximately 300 other villages/production sites possess favorable wind regimes. For Eritrea as a whole, the potential for replicating small-scale wind as a stand-alone application or in a hybrid system with PV and/or diesel for rural electrification is around 25–35 megawatts.

Worldwide, small-hydropower (SHP) produces 59 GW of power, with over half of that capacity installed in developing countries. Around 50 million rural homes receive power from small-hydro, mostly in China. Between 2002 and 2004 alone, 350 townships in China received 200 megawatts of small-hydro capacity through the country's Township Electrification Program.[99]

SHP is characterized by a high degree of technological maturity, easy maintenance, and low energy costs.[100] As demonstrated by India, a developing country can establish indigenous manufacturing of all components.[101] Challenges include low power in lean periods and the fact that many potential hydro sites are inaccessible due to difficult terrain or other circumstances.

Case Study: Small-Hydropower in Nepal[102]

In Nepal's rural areas only 6 percent of people have access to electricity. The Rural Energy Development Program (REDP) was initiated by the Nepalese Ministry of Local Development in 1996 in 15 districts and has since led to the implementation of program activities by some 100 Village Development Committees.

REDP has been successful in scaling up micro-hydro plants, through the development of Community Energy Funds (CEFs), a basket of funds mobilized by the local people from equity contribution, loans, investment, grants, and subsidies. Tariffs are collected from the consumers and deposited into the CEF, out of which the cost of operation and maintenance is paid.

The most useful and effective end uses for the electricity generated by the micro-hydro plants include clean and better lighting, agro-processing mills, rural enterprises such as a rural bakery, thangka painting, incense stick making, rural soap making, poultry farming, a computer institute, and recreation centers. Other important end uses and benefits include the added facility of irrigation and drinking water, improved health and sanitation, and well-managed greening of the surroundings.

As mentioned previously, around 16 million rural households cook and light their homes using biogas produced in household-scale anaerobic digesters.[103] Recent developments in biomass gasification technologies, for example development of engines that run on 100-percent producer gas, have made it possible to deploy biomass-based systems to meet total energy requirements, including cooking, lighting, and motive power.[104]

Tens of thousands of mini-grids exist in China, while hundreds or thousands exist in India, Nepal, Viet Nam, and Sri Lanka. Village-scale mini-grids in remote areas or on isolated islands have traditionally been powered with diesel generators or small hydro. However, generation from solar PV, wind, geothermal, or biomass, often in combination, can replace or supplement diesel in these grids. Only around 1,000 such hybrid mini-grids exist in the developing world, mostly in China, where they have been installed through the Township Electrification Program since 2002. Out of the 1 million people who received electricity in China through this program, about 250,000 households were electrified with solar PV, wind-solar PV hybrid systems, and small hydro systems.[105]

There is limited experience and a variety of challenges associated with organizing and managing mini-grid systems.[106] Nonetheless, in areas of sufficient density they are thought to be better than solar home systems because the main equipment is operated and maintained centrally, mini-grids have all the features of grid power supply, and they can power 8–10 hours daily.[107] Renewable energy-based mini-grids are less dependent on larger-scale infrastructure and could be placed in service faster, especially in rural areas. Renewables can also be helpful in reducing uncertainties with respect to fuel price volatility and availability, and hence, their value in reducing risks is worth mentioning.[108]

The combined capacities of the wind generator and solar module can generate the required energy at lower cost than solar PV alone.[109] Communities can select and combine the least-expensive mix of technologies, which permits the best and most cost-effective solutions, given local circumstances.

RETs Can Create Opportunities for Income Generation

Experience has shown that despite efforts to promote commercially viable RETs, affordability is a key barrier to their widespread adoption. Therefore, development experts are looking toward RET projects in off-grid areas that focus on productive uses of renewable energy (PURE) as the entry point for market development.[110] Productive uses of energy involve the application of energy to generate goods or services either directly or indirectly for the production of income or value. Productive uses of energy can include services that are indirectly linked to income generation (e.g., clean water, healthcare, education, telecommunications), since developing skills and maintaining health are both essential for productivity and human development.[111]

When energy projects are intentionally coupled with development initiatives, it is clear that in rural areas, small amounts of energy can bring about a big difference in productivity and income, particularly in agriculture. They do this by spurring the creation of micro-enterprises (MEs), stimulating income directly by engaging people in using local resources and selling energy services, as well as indirectly through gains in productivity or expanded economic activity resulting from new energy inputs.[112]

The productive uses of energy that contribute most to economic development are associated with agriculture, as process heat and motive power is found to be more crucial to income-generation than lighting. By enabling food preservation (e.g., drying, smoking, chilling, and freezing), RETs can boost incomes by preventing loss of a significant fraction of the harvest between gathering and commercialization. This is particularly critical for producers who are distant from markets or have difficultly accessing them. RET-enabled preservation also creates the ability to store goods for later sale during different seasons, resulting in better income distribution over time.[113]

Wood fuel sold at market in Burkina Faso

Case Study: Renewable Energy for Food Preservation in Thailand[114]

Thailand produces 9.6 thousand tons of bananas for drying each year. Banana chips processed by a solar dryer sell for 15.08 Baht (US $0.36) per kilogram, while chips dried conventionally (over fire or on shelves in the sun vulnerable to insects) go for only 8.62 Baht (US $0.21) per kilogram. The increased income from drying all bananas with solar technology is $1.5 million per year. Even greater, however, is the difference in value gained by solar-drying rubber over conventional drying, $71–107 million more in earnings, given the 2.9 million tons produced each year.

The solar units aren't cheap, though: a solar dryer for bananas typically costs $4,900 for a 100-kilogram per batch capacity, while a rubber dryer is about $23,000 for a 15,000-sheet per batch capacity. The latter was put to use in a community of 119 households, at an investment of $195 per household. While this is still high given the average monthly income of $222 in rural Thailand, the payback period is 2–5 years for bananas and 4 years for rubber. The improved dryers are built with locally available material and technologies and the construction requires special training, thus building the capacity of local workers. Once the items are put in the dryers, production does not require much attention, allowing the owner to engage in other activities.

Rural poor spend a significantly greater proportion of their income on water than do the rich; the price they pay water vendors is often ten times more than the tap price.[115] RETs provide a local, reliable, and safe drinking-water supply that can pay for itself over time and be maintained with savings from avoided fuel costs. Income can be generated directly through selling water. (See case studies for MDG 7, pp. 32–35) RET-powered irrigation projects that pump water for farms, market gardens, and ranches have also demonstrated a positive impact on income generation, food production, livestock products, and access to nutrition.[116] Approximately 1 million mechanical wind pumps are in use for water pumping, primarily in Argentina, with large numbers also in southern Africa. More than 50,000 solar PV pumps are installed worldwide, many in India.[117]

Case Study: Solar Water Pumps in India and Mexico[118, 119]

In India, the Punjab Renewable Energy Development Agency (PEDA), with support from manufacturers and financiers, installed 100 solar PV systems to provide a continuous supply of water for agriculture. Farmers previously had to rely on sporadic connection to the grid or on diesel generators. The newly-assured supply of water increased the productivity, and hence income, of small and marginal farmers. Moreover, all the replaceable parts of the solar PV pumping system were fabricated locally, providing jobs. The one-time acquisition cost, when spread out over the system life of 20 years, makes solar PV systems inexpensive in comparison to diesel-run generators. And the avoided annual cost of diesel fuel, Rs 18,000 (US $418), more than covers the cost of maintenance, around Rs 1,950 (US $46) annually.

While only 5 percent of Mexico's population lacks access to the grid, in absolute terms that amounts to 5 million people. The Mexico Renewable Energy for Agriculture project aims to install 1,150 solar water pumps for livestock farmers living off-grid. The cost of the pumps is currently covered by a combination of Mexican government and GEF funding, with farmers paying the rest. The pumps are predicted to raise the income of livestock farmers by 19–44 percent, depending on the region. The Mexican government has expressed interest in scaling up the project dramatically, as there are 600,000 rural farmers in Mexico off-grid. Just providing 30 percent of these farmers with pumps over five years, however, would require $87 million in total investment.

Non-agricultural micro-enterprises also represent an important part of the economic activity in developing countries. Micro-enterprises are very small businesses that produce goods or services for cash income, usually with limited access to capital, few employees, and a home-based set-up. In lower-income countries they often employ a third or more of the labor force.[120] The following table from the Asian Institute of Technology's paper, "Application of Productive Uses of Renewable Energy for Small, Medium, and Micro Enterprises," presents the most common energy services for income generation that are provided by RETs.

TABLE 3: Energy Services and Income Generation[121]

Energy Services	Income-generating value to rural households and enterprises	Renewable Energy Options
Irrigation	Better yields; higher value crops; greater reliability; growing during periods when market prices are higher	Wind, solar photovoltaic (PV), biomass
Illumination	Increased working hours	Wind, solar PV, biomass, micro-hydro, geothermal
Grinding, milling, husking	Creation of value-added product from raw agricultural commodity	Wind, solar PV, biomass, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value-added product; preservation of produce to enable sale to higher-value markets	Biomass, solar thermal, geothermal
Refrigeration, ice making (cold generation)	Preservation of produce to enable sale to higher-value markets	Wind, PV, biomass, micro-hydro, geothermal
Extracting	Production of refined oils from seeds biomass	Solar thermal
Transport	Access to markets, public transport	Biomass (biofuels)
Computer, internet, telephone	Access to market news; entertainment; co-ordination with suppliers and distributors; weather information	Wind, solar PV, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end users	Wind, solar PV, biomass, micro-hydro, geothermal

RETs may use locally available resources to provide micro-enterprises thermal, mechanical, or electrical energy while minimizing the adverse environmental impacts. The benefits of RETs are of particular relevance to micro-enterprise, as energy-related expenditures can account for up to 70 percent of total running costs in the most energy-intensive cases. And in the cases where fuel wood or other local biomass is used, as in the tea, silk, or brick sectors in Sri Lanka, deforestation can become an important concern. In India, for example, the silk-reeling industry annually consumes an estimated 120,000 tons of fuel wood in cottage-basin ovens and 105,000 tons of other locally available biomass.[122]

Case Study: RETs for Micro-Enterprise in Bangladesh, Nepal, and India[123]

Until recently, rural areas of Bangladesh have had virtually no telecommunication facilities. With a loan from Grameen Shatki, however, one woman bought a solar home system for lighting and charging mobile phones. The total cost of the system was about US $250, and the financial scheme involved a 25-percent down payment (US $62.50), 75 percent by installment with an 8 percent service charge over a repayment period of 2 years. During this period, the monthly loan repayment was therefore equal to US $8.54. On average, after deducting the loan repayment, she earns US $91 per month from the phone rental service.

The implementation of a 50 kW micro-hydro power plant in the village of Barpak in the Nepalese district of Gorkha generated two direct jobs (for the operation and maintenance of the plant) in the energy- producing sector and more than 80 indirect jobs with the creation of eight small enterprises (mills, furniture factory, bakery, hand-made paper manufacture, etc.) benefiting from the availability of electricity.

In India, silk produced with heat from biomass gasifiers is of superior quality, with a higher market price that allows silk reelers to increase their income by Rupees 200 per day. Silk reelers switching from traditional biomass ovens to biomass gasifiers also increased their silk yield by 3.7 percent. The biomass gasifier, specifically designed for the silk industry, is reported to have a payback period of one year.

The diversification of livelihood strategies is key to poverty alleviation, as it enables people to better adapt to long-term changes. The domestic production of renewable energy helps create autonomy by reducing income dependence on agriculture and by fostering the creation of a local web of economic activities that are mutually reinforcing. This diversification also contributes to the economic and energy security of a nation.[124]

Village cooperatives in several regions have demonstrated the capacity to develop local manufacturing of RETs, creating a source of employment not only for the manufacturers, but also for installers and distributors, with additional business opportunities for those who stock spare parts and sell raw materials. Communities can also build up an export market to neighboring regions and countries.[125]

Case Study: Ram Pumps in Tanzania[126]

Ram pumps are water-pumping devices powered by falling water. They require no other external power and run automatically for 24 hours a day with minimum maintenance. Ram pumps are used mostly to supply water for domestic and livestock supplies, but have also been applied successfully to lifting irrigation water from streams or raised channels. About 40 ram units are operating in Tanzania, almost all of which were manufactured locally and installed by Jandu Plumbers and have been in operation for more than 10 years. In several rural districts, ram pumps supply water to as many as 1,500 inhabitants and, in addition to being used domestically, generate income from irrigated coffee, animal husbandry, and supply of water to other villages.

Although much more affordable than imported hydraulic rams, Jandu rams are still too expensive for most villages, costing $300–2,600, depending on the capacity. Fortunately, the pumps have very low running costs, and the savings accrued from replacing diesel pumps is freed-up for other economic activities. Data from Tanzania indicates that the use of ram pumps presents opportunities for both users and manufacturers because local experts install the pumps, and the need for metal workers and construction of storage systems adds to employment opportunities. So far, micro-credit to facilitate affordability of the pumps has been crucial to their wider deployment.

For some countries RETs are already spurring industrial growth, creating jobs and business opportunities for both the urban and rural poor, boosting involvement of the local supply chain, and bringing in foreign direct investment, while also increasing access to global markets and trade. Roughly 400,000 jobs in Brazil are attributed to the ethanol industry, 250,000 in China are attributed to solar hot water, and 11,000 jobs in Nepal are created by the production of biogas.[127]

Though more difficult to quantify, RETs also create value through their contribution to energy security, environmental sustainability, and human health. Because renewable energy development can free up financing from oil production and consumption, there is great potential to contribute to new development initiatives. Biofuels, which can be used for both transportation and electric supply, are particularly suited to replace oil derivatives, reducing imports of fossil fuels.

Among the conditions found in many developing countries that may warrant incorporation of RETs into their energy portfolios are:

- Large labor forces that could be trained to manufacture labor-intensive RETs.
- Abundant domestic energy resources, such as sunlight, biomass, and wind.
- Limited existing energy infrastructure, providing leapfrog opportunities.

- Ability to establish local manufacturing of RETs, leading to larger domestic markets and opportunities for export growth.
- Potential to be cost-competitive in RET industries due to lower wage costs, at least in the early stages of economic development.
- Existence of large agricultural sectors in need of new revenue streams.[128]

RETs deserve specific recognition for their potential to revitalize agricultural economies. Biofuels and wind power in particular could provide a new source of business for farmers and agricultural processors, creating economic opportunities and jobs in rural areas that have suffered decades of falling crop prices. Agriculture still plays a significant role in the economies of developing countries, providing 68 percent of total employment and 24 percent of GDP in low-income countries.[129] Marginal land that is unsuitable for most cultivation can be planted with faster-growing cellulose energy crops that are less resource intensive, are relatively drought resistant, and require less maintenance.[130] Some of the world's most valuable wind resources sweep across some of the poorest farmlands. Windy, semi-arid conditions might produce limited revenue for farmers and ranchers, but wind energy could offer a valuable new crop to generate income on cropland parched from drought.[131]

Biofuels offer an excellent platform to simultaneously advance various MDG objectives. They hold the promise of contributing to rural development through the establishment of new crop plantations, distilleries, and other agro-industrial facilities, resulting in new agricultural and agro-industrial jobs and in new products with guaranteed market absorption (e.g. fertilizers, animal feed).[132] Diversifying to high-value energy crops not only brings substantial benefits to the macro-economy, but can also be pro-poor by helping to create jobs across a broad spectrum of the economy.

The potential for RET trade among developing countries presents significant economic opportunities as well. Brazil accounted for half of all international shipments of ethanol in 2004 (see case study, below), and India was the third largest importer. And as existing biodiesel markets in Indonesia, Malaysia, and the Philippines continue to develop, biofuel trade out of and within the developing world will expand rapidly (see case study on Malaysia, page 26.)[133] China, meanwhile, is already a world leader in manufacturing micro and small wind turbines, and multiple developing countries have established production of solar PV modules with potential to export.[134]

While kerosene and LPG are rarely available at prices affordable to the rural poor, biofuel can be produced domestically to replace conventional fuels and traditional biomass. Fuel ethanol production increased 13.6 percent in 2004, reaching almost 33 billion liters. World production of biodiesel fuel, based on vegetable oil and fats, is smaller but has been growing even faster, nearing 1.8 billion liters in 2003, up 18 percent over 2002.[135] The viability of converting sugarcane to ethanol for motive power has been fully demonstrated in Brazil. Thailand, India, Colombia, Malaysia, and the Philippines have also set targets to spur the development of biofuel.[136]

Case Study: Ethanol Use in Brazil[137]

The largest commercial effort to convert biomass to energy anywhere in the world today is the substitution of sugarcane-based ethanol for gasoline in passenger cars in Brazil. Established in 1975 in response to the first oil crisis, the country's ethanol program, Proalcool, substituted more than 200 billion liters of gasoline between 1975 and 2002. During the first ten years of the program, ethanol production increased at an annual rate of 35 percent. Although production then declined steadily between 1992 and 2000, in response to a rise in world sugar prices, this trend has since reversed dramatically: in 2004, Brazil exported 2.4 billion liters of ethanol.

Proalcool provides stable employment for 500,000 people on sugarcane plantations and another 500,000 working in alcohol/ethanol production, transportation, blending, and other activities. Estimates indicate that every 1 million tons of sugarcane processed per year generates 2,200 direct jobs (1,600 in agriculture and 600 in industry). Agricultural supervisors and skilled industrial workers account for 30 percent of these jobs; medium-skill workers (e.g., truck and tractor drivers) for 10 percent; and unskilled laborers (doing planting, cultivating, and harvesting, and low-level industrial work) for the remaining 60 percent.

The estimated family income of cane cutters is $220 per month, 50 percent higher than the average family wage in Brazil. Special legislation mandates that 1 percent of the net sugarcane price and 2 percent of the net ethanol price go to improving services for sugarcane workers, including medical, dental, and pharmaceutical care and better sanitary conditions. Also, sugarcane bagasse (residue from sugarcane crushing) generates all energy needs for the mill as well as some surplus for distribution in rural areas. Several examples of electricity surplus generation exist in Brazil, mainly in São Paulo state.

Case Study: Biodiesel Production in Malaysia[138]

Europe leads global production of biodiesel, which it converts mostly from rapeseed oil. But several developing countries have the potential to make significant inroads into the market. In early 2005, the Malaysian Palm Oil Board (MPOB) invested $10.5 million to build the country's first biodiesel plant. Slated for completion in three years, the plant will produce 4.35 million liters of biodiesel a month, most of it for export to Europe.

Malaysia is the world's largest producer of palm oil, followed closely by Indonesia, and a Malaysian conglomerate recently developed its first commercial clonal oil palm, with the potential to enhance yields by 30 percent over current seedling materials. Because palm oil is already the world's cheapest oil, large producers of the commodity are well positioned to capitalize on Europe's growing appetite for alternative fuels. The Malaysian government is now creating a domestic energy policy that will use palm oil as a blend with diesel. Biodiesel will be the fastest-growing market for palm oil exports in 2005 and subsequent years, and other oil-based crops cultivated in developing countries, such as coconut and jatropha, have the potential to follow suit.

MDG 2: EDUCATION

Target: Ensure that all boys and girls complete a full course of primary schooling.

For a school without electricity, delivering quality education is a vast challenge. The problem goes well beyond a lack of bright light for reading. Absence of power also means that schools can't use the technologies central to modern education, from computers to photocopiers. "Denied the tools to succeed in their work, the most experienced and skilled teachers shy away from schools without electricity, further exacerbating the problem. Without good teachers and good technology resources, students predictably under-perform, drop out, and ultimately remain unemployed."[139] The infamous "digital divide" increasingly segregates children educated in schools without energy. Energy is necessary to bridge the technology and education gap, to enable rural areas to become more economically sustainable, and to reverse the trend of migration from rural to urban areas.

Particularly in rural areas where conventional fuels are not affordable to the poor, RETs can make important contributions to education by providing electricity to schools and creating a more child-friendly environment that improves attendance (see case study, p. 27). Lighting in schools helps retain teachers, especially if their accommodation has electricity. Access to educational media (overhead projectors, computers, printers, photocopiers, science equipment) and communications increases educational opportunities and the opportunity for distance learning.[140]

Case Study: Scaling for Sustainability in Latin America[141]

Enersol's EduSol program in unelectrified areas of Latin America and the Caribbean enables communities to operate "electronic learning resource centers" to improve the quality of their children's education with small, efficient renewable-energy systems. The centers, featuring 2–4 energy-efficient laptop computers and educational software powered by a small PV array (100–200 W), are primarily located in one- or two-room elementary schools serving up to 100 students.

Enersol helps implement projects that the communities can afford to maintain, finding that small systems incorporating efficient technology are suitable options for the populations they serve. Each system provides enough energy to run the computers, a printer and other peripherals, and a lighting system, but has maintenance costs affordable for the community. One advantage is that both technologies—the computing and the PV—are modular, so centers can start at a scale that reflects the beneficiaries' ability to pay the ongoing costs, and expand over time as their ability and need grow.

Anecdotal evidence shows that the systems are compensating for some of the challenges of multi-grade teaching (one teacher teaching two or more grades at once) by allowing older children to use the computers (for research, for example), and to actively construct their own learning. By mid-2005, Enersol had implemented 26 EduSol projects in the Dominican Republic, Honduras, and Haiti, serving over 1,500 children and their families.

The arduous task of collecting fuelwood and water keeps children, especially girls, out of the classroom.[142] By providing sustainable energy for cooking and space heating at low operating costs, improved stoves and alternative fuels can free up this time for education. The use of RETs to provide electricity in the home also frees time for education—home lighting enables reading and studying beyond daylight as well as the opportunity to engage in income-generating activities for longer hours, the extra earnings from which can be used towards school fees (see case study on Swaziland, below). RETs can also enable a local, reliable, and safe drinking-water supply that increases sanitation levels, reducing ill-health and disease in children and raising attendance in school. Surveys by the Tanzanian Government have found children 12 percent more likely to attend school if they live within 15 minutes of a drinking water source than if they live more than one hour from such a source.[143]

Case Study: Solar Powered Classrooms in Swaziland[144]

In Swaziland, many pilot projects applying solar photovoltaics to rural electrification failed as panels either fell into disrepair or were stolen. Then in 1998, UNESCO's World Solar Program approved $30,000 in funding to establish a solar village in the country, under the condition that the project emphasize the importance of full community involvement. The project identified Mphaphati in the Lower Kaphunga region, a village with a high degree of local cooperation and home to a primary school with 170 children, a small shop, and a community-managed vegetable garden. Even before the plans were drawn, an extensive awareness campaign and capacity-building program was initiated, and a solar committee was established in the village. The committee agreed the project would provide electricity for basic lighting in three classrooms, for operation of educational audio-visual equipment, and for a water pump for the community garden. The teachers' houses were also provided with solar home systems (SHS).

Although the equipment was donated, the community was responsible for funding system maintenance. As a result, they established a self-imposed school fee of $0.45 per term for each child, as well as a $1.35 per-month fee from each teacher for use of the SHS. Members of the garden paid $0.45 per month for use of the water pump. The audiovisual equipment was also used to provide a rural cinema, charging viewers $0.09 to attend. These fees have enabled the community to maintain the project. By comparison, the community calculated that average expenditures on candles and dry cell batteries were around $3.60 a month. At the request of the Swazi government, the Renewable Energy Association of Swaziland has since reviewed the project and developed a model for replication throughout the country.

MDG 3: GENDER EQUALITY

Target: Eliminate gender disparity in primary and secondary levels of education.

Worldwide, an estimated 570 million households rely on traditional biomass for cooking, representing almost one-third of the global population.[145] In most societies, it is women and girls who cook and spend time near the fire, and in developing countries they are typically exposed to very high levels of indoor air pollution, many for 3–7 hours a day over many years.[146] By providing clean energy for cooking, RETs reduce the disproportionate health burden of indoor air pollution on women. (See case study on Mali, below.)

RETs substitute the need for traditional biomass, alleviating the drudgery of fuel wood collection and promoting gender equality and women's empowerment. Women in rural households typically devote 25 percent or more of total domestic labor to wood collecting. Water collection is another difficult and time-consuming chore for rural populations, and like fuel wood collection is usually the responsibility of females, preventing many girls from attending school. Household surveys from Burkina Faso, Ghana, Tanzania, Uganda, and Zambia show that 87 percent of trips in Africa take place on foot and that the daily transport burden of a typical adult woman is equivalent to carrying 20 kilograms for 1.4–5.3 kilometers.[147] Availability of RETs can free women's time from survival activities such as gathering fuel wood, fetching water, cooking inefficiently, processing and hanging crops, and manual farming work, allowing them opportunities for education and enterprise development. (See case study on Senegal, page 29.)

Case Study: Empowering Malian Women Through Adoption of Biodiesel Engines[148]

The multifunctional platform initiative of Mali, supported by the U.N. Development Programme and other partners, seeks to reduce rural poverty and improve the situation of women through provision of affordable, decentralized energy services. The multifunctional platform (MFP) is a diesel/biodiesel-powered engine that can run a variety of equipment, including grinding mills, battery-chargers, vegetable or nut oil presses, welding machines, and carpentry tools. The engine can also support a mini grid for lighting, refrigeration, and electric pumps for small water distribution networks or irrigation systems.

Because of the engine's simplicity, it can be installed and maintained by local mechanics. Spare parts can be obtained in West Africa due to the wide availability of diesel engines. Nuts from the local Jatropha curcas shrub, which can be grown in a sustainable manner, can be converted into liquid fuel for use in the engine. Mali has about 10,000 kilometers of Jatropha hedges with a growth rate of 2,000 kilometers per year, representing a potential output of 1,700,000 liters of oil per year. The average length of the hedges in areas where they are most prevalent is 2–15 kilometers per village, with a maximum of up to 40 kilometers per village.

Jatropha oil is inexpensive to produce and requires the energy equivalent of 10 percent of the oil obtained to produce in mechanical presses. At an estimated cost of $4,500 for the engine, rice huller, stone-mill, battery-charger, and platform housing, the platform is comparatively cheap to buy, install, maintain, and replace. Between 30–40 percent of the cost is financed by the women's association, often with financial support from the rest of the community, and a one-time subsidy of approximately $2,500 is provided by the project on a grant basis. In each village, around 800 clients, mostly women, buy energy services from the platform.

Studies show strikingly positive impacts. Annual income per participating woman has risen from $40 to $100 in Mali and freed 2–6 hours of time per day, depending on the services of the platform. The platform has also stimulated micro-level business activities for village men in blacksmithing, carpentry, and mechanics as well as small-scale enterprises that manufacture, install, and maintain the platforms. Villages experienced increases in the number of girls in schools and improved levels of functional literacy among women. Since users pay for the service provided, women's management groups have been able to accumulate savings for operation and maintenance costs.

Case Study: Using Wind Power to Free Up Women's Time in Senegal[149]

For years, agencies in Senegal have been struggling to find ways to provide local water supplies for villages and agricultural production. The water accessibility rate in the capital city, Dakar, is 96 percent, but in rural areas, people trek tens of kilometers to fill their buckets. The consequences of this are all too familiar. Fewer girls attend school (64.8 percent, compared to 73.9 percent of boys), and women are disproportionately hit by poverty. Other effects include water-related diseases and insufficient water consumption: in 2001, average per capita consumption was 28 liters per day, below the World Health Organization's recommended daily minimum intake of 35 liters.

By 1983, thanks to funding from the government of Argentina, more than 200 wind-pumping systems were installed in Senegal. But just three years later, a study found that 60 percent were no longer operational. The situation then deteriorated further, with all systems falling into disrepair.

In the mid-80s, the Lay Volunteers International Association (LVIA) took over installations and was careful to incorporate a maintenance segment into their projects, emphasizing community ownership. Of the 150 pieces of equipment that have been installed by LVIA, 75 percent are still operational. Production and marketing of equipment is now entirely in the hands of a local economic interest group (VEV: Vent, eau pour la Vie), as is the supply of maintenance services. Over 95 percent of the technology is made from Senegalese materials. Repairs and replacements are paid for by the village management committees.

Under the VEV, market gardeners pay an annual lump sum that is 10 times lower than the social tariff applied by the nation's private water-operating company. Women are responsible for managing the pumps and also sell water at drinking fountains for cattle rearing and household needs. They claim part of the income generated, while the majority is put back into a fund for repairs and a stock of spare parts. Youth groups cultivate crops that would otherwise be off-season, and women are responsible for selling them, boosting food security and creating extra income. Local-service providers and manufacturing enterprises receive additional business.

MDGS 4, 5, AND 6: HEALTH

Targets: Reduce by two-thirds the mortality rate among children under five.
Reduce by three-quarters the maternal mortality ratio.
Halt and begin to reverse the spread of HIV/AIDS.
Halt and begin to reverse the incidence of malaria and other major diseases.

By providing energy to remote areas, RETs improve rural health for refrigeration of medicine, equipment sterilization, and safe disposal of medical waste by incineration. RET-supplied electricity also provides access to health-education media. (See case study on Burma, below.) All of these improvements create better medical facilities for maternal care. (See case study on Cuba, page 30.) For health care centers, photovoltaics (PV) are typically used to meet lighting and specific appliance needs, representing 0.24-1.0 kilowatts per center.

Case Study: Powering Rural Clinics in Burma[150]

In Burma, Green Empowerment has installed solar PV panels in 18 rural clinics to improve basic living conditions and provide quality health care to the thousands of people living in the conflict-ridden east. A total of 2,340 watts of power illuminating the clinics has allowed indigenous Karen refugees and internally displaced people access to medical care, making these clinics critical to refugee survival. The medics treat landmine victims and other casualties of the conflict, as well as patients affected by malaria and other illnesses resulting from harsh conditions.

An estimated 54,000–90,000 people have benefited from the clinics since August 2003. The solar systems allow medics to address nighttime emergencies, have proper lighting for medical procedures, and use electric medical devices and laptop computers. Having built the systems themselves, the medics are fully trained to install, operate, maintain, and move the specially designed mobile systems. Each unit consists of one 130-watt solar panel, 1 deep-cycle battery, 2–3 fluorescent 20-watt lights, 1 LED light, 1 12-volt outlet, and 1 charge controller. The total cost of the project is estimated at $55,712.

Case Study: Improving Health and Maternal Care in Cuba[151]

El Mulato, Cuba, a community of 400, is so remote that when a health clinic was built the building materials arrived by helicopter. In 1989, El Mulato was electrified with photovoltaics. As of May 1998, 170 additional clinics in the remote mountain regions of Cuba were also electrified. All of the systems included lights, a vaccine refrigerator, and other medical equipment such as electrocardiographs and x-ray machines. Radiotelephones were installed to provide communication. As a result, the health situation in El Mulato improved greatly. Electricity brought opportunities for women as well, resulting in a decrease in the average birth rate from 5–6 children per woman to 2–3, and lowering the infant mortality rate.

The use of RETs for cooking reduces exposure to indoor air pollution as well, improving health. The 570 million households that continue to depend on traditional biomass for their energy needs are exposed to high levels of indoor air pollution containing a range of health-damaging pollutants, such as small particles and carbon monoxide.[152] According to *World Health Report 2002*, indoor air pollution is responsible for more than 1.6 million annual deaths and 2.7 percent of the global burden of disease, making it the second-biggest environmental contributor to ill-health behind unsafe water and sanitation. Researchers attribute 3–4 percent of total mortality worldwide to indoor air pollution. There is consistent evidence that exposure to indoor air pollution can lead to acute lower respiratory infections in children under five and to chronic obstructive pulmonary disease and lung cancer (where coal is used) in adults.[153]

Studies from Asia, Africa, and the Americas have shown that indoor air pollution levels in households that rely on biomass fuel or coal are extremely high; for example, typical 24-hour mean levels for PM-10 (particulate matter) in homes using biomass fuels are around 1000 μg/m3 (micrograms per cubic meter) compared to the current limit of 150 μg/m3, set by the U.S. Environmental Protection Agency.[154]

In addition to women, young children are also disproportionately exposed to dangerous indoor air pollution while carried on their mother's back, breathing smoke from early infancy. As much of the disease burden due to indoor air pollution falls on children under five years of age, RET interventions will help achieve a significant reduction in child mortality.[155]

India currently bears the largest number of indoor air pollution-related health problems in the world, with 75 percent of households burning traditional biomass. An estimated 500,000 women and children in India die each year as a result.[156]

A number of technical interventions can be employed to reduce indoor air pollution. Stoves can be improved to achieve better combustion and greater efficiency, and flues, hoods, or chimneys can be attached to remove smoke. Changes in kitchen design can increase ventilation and control the distribution of pollution. Most effective, however, is the switch from solid fuels (biomass, coal) to RETs such as biogas, biofuel, and solar. (See case studies on China and Africa, pp. 17–18.)

An estimated 220 million people have received or purchased "improved" biomass stoves as a result of various programs and markets in recent decades, primarily in China, India, and Africa.[157] While this technology could be dismissed as primitive, given the widespread use of fuel wood among the rural and peri-urban poor, use of improved cook stoves can bring significant advantages, particularly with regard to the health of the population. A case history that traces the progress of stove development from early failures to acceptance can be found in East Africa. (See case study on Kenya, p. 31.)

Each "improved" stove represents a 15–30 percent typical efficiency gain in household biomass use. In recent decades, urban areas in developing nations have experienced the highest penetration rates of these stoves. However, it is in rural households where these stoves are most critical, as rural areas are not endowed with the infrastructure that would bring cleaner fuels, nor do residents typically have the income to pay for such fuels even if they were available.

Case Study: Improved Stoves in Kenya[158]

Almost 1 million households in Kenya now cook with the Kenyan Ceramic Jiko (KCJ), a stove consisting of a metal casing with a ceramic lining that helps to direct 25–40 percent of the heat from a fire to a cooking pot. The first improved stoves appeared in the country in the early 1980s, with limited success, but by the mid-1980s designs gradually improved. Extensive training programs established by aid groups and women's organizations led to dramatic gains in acceptance for the more-efficient stoves.

The KCJ in particular has had a considerable impact on household finances. Typical savings of .65 tons of fuel a year frees up about $65 per household. However, the Jiko was mostly used in urban areas, as the $2–5 stove price was prohibitive for many rural households that could collect their own firewood and cook over open fires. Following an alliance between leading government and aid organizations in Nairobi and women's groups, a simplified and affordable variant named the Maendeleo or Upesi stove was created. The Upesi stove costs as little as $.80 and uses 40 percent less fuel than open fires, with up to 60 percent less smoke.

The intended beneficiaries of the 1995 Upesi Rural Stoves Project were women and their families in rural households of western Kenya. More than 100,000 stoves have been constructed to date. At the final project evaluation in 2000, users of the Upesi stove reported savings of up to KShs. 7,200 (US $94) per year, health cost savings of KShs. 260(US $3) per year, and timesavings of about 10 hours per month.[†] Acute respiratory infections were reportedly reduced by 60 percent in children and 65 percent in mothers, while conjunctivitis dropped by 70 percent in children under five and 67 percent in mothers.

A total of eight producer groups, or at least 50 women, were trained directly by the project, as were at least 23 promoters, eight retailers, and five distributors. On average, producers devoted 2–3 days a week to stove production. Every active group member could sell 510 stove liners and earn KShs 15,300 (US $200) in a year. Records indicate that the project has succeeded in increasing sales of rural stoves from 30 percent to 75 percent in the last three years. Variants of the Kenya ceramic Jiko have made their way to Tanzania, which has more than 54,000 stoves; Sudan, which has 28,000; Uganda, which has 25,000; and Zambia and Burundi, which have 5,000–10,000 each.

Solar PV, solar water heating, and passive solar space heating (see case study on China, below), have all been utilized to reduce the use of traditional biomass. An estimated 10 million households worldwide have solar hot water (SHW) systems. In warm climates where the technology is well-established, SHWs (usually augmented by an electrical immersion heater) are fully economical. The technology is characterized by accessible investment cost, complementarity with other water-heating systems, and significant fuel savings. While more research is needed to produce simpler and cheaper models without large reductions in efficiency, local manufacturing of SHW heaters has been demonstrated in several developing countries.

SHW systems could meet close to 50 percent of household hot water requirements, as well as industrial and commercial thermal requirements.[159] Use of these systems can also be expanded to certain production and services (meal preparation, bakery, marmalades, laundry, etc.). As such, solar water heaters may partially or wholly substitute the use of electricity, LPG, and oil for water heating in areas with sufficient solar radiation.

Integration of passive solar elements into the design of schools, health care centers, and other infrastructure can also reduce the demand for heating fuels, while improving indoor air quality.

Case Study: Heating Health Care Centers in Rural China[160]

To improve the quality of health-service delivery to the rural poor, the government of China is implementing the Health VIII project in 71 counties in seven provinces. With assistance from the World Bank, the project aims to

[†]Rural wages average KShs. 800 per month.

improve rural health through the creation of Township Health Centres (THCs) that provide basic health services for nearly 80 percent of the rural population. Unfortunately, many of the first THCs built experienced severe heating problems, particularly in the three coldest provinces of Qinghai, Gansu, and Shanxi, where heating is required for over six months of the year to provide adequate health services.

In most remote communities, coal is not locally available and transportation is difficult. Moreover, coal is expensive, which increases operating costs and limits service when supplies are low. Burning coal in the typical THC coal stove increases carbon dioxide and particulate levels, with threatening carbon monoxide levels at times, and the high fluoride content in the coal adds to indoor air pollution.

However, in three of the THCs passive solar design elements were integrated into construction, using grant funds from the Asia Alternative Energy Program and the Chinese Ministry of Health. Because they demonstrated better indoor comfort, air quality, and lower coal consumption, 30 more passive solar THCs are now being built. In a Gansu clinic, the passive solar design saved more than 34 tons of coal that would have cost US $1,632 over the 5.5-month heating season. Among design and construction lessons learned were the need for higher insulation levels, better quality-control during construction, and more efficient space allocation in the building design.

MDG 7: ENVIRONMENTAL SUSTAINABILITY

Targets: Integrate sustainable development into country policies and programs.
Reduce by half the proportion of people without sustainable access to safe drinking water.
Achieve significant improvement in the lives of at least 100 million slum dwellers, by 2020.

The transition to renewable energies will help alter the current patterns of energy production and consumption that threaten the environment at both the local and global scales. The burning of fossil fuels and the cutting of forests are contributing to environmental degradation and climate change.

"The burden of environmental degradation falls disproportionately on developing countries that are limited in their capacity to respond to climate change and depend on environmentally sensitive activities such as agriculture and [fisheries]."[161]

RETs Can Improve Water Quality

Water and sanitation are among the most important determinants of public health and rank at the top of the World Health Organization's list of primary health care components. The control of endemic and emerging diseases is naturally linked to an intact ecosystem's ability to mediate climate change, mitigate water quality and distribution, and provide alternative hosts for existing and emerging disease vectors. Therefore MDG 7 includes a target to reduce by half the proportion of people without sustainable access to safe drinking water.

Degraded ecosystems with a considerable amount of standing water and little natural control of invertebrate populations are ripe for high incidence of water- and insect-borne disease. These diseases, such as malaria, dengue fever, and diarrheal diseases, will inevitably take the lives of infants ill-prepared to withstand their symptoms.[162] By producing energy for pumping and sterilization, however, RETs can provide locally reliable and safe water supplies that are essential for sanitation. In turn, RETs reduce time spent gathering water, thus increasing time available to engage in income-generating activities.

Solar PV systems become essential to meeting certain electricity and water pumping requirements in regions where other renewable resources, such as wind, water, and biomass, are not abundant. Due to their high cost per power unit use, however, they rarely represent an income-generation tool. The exceptions could be water pumping and the supply of certain services and lighting, though the cost of the systems places them only within reach of middle-and-high-income consumption sectors.[163] Commercial projects for solar PV-powered drinking water, both pumping and purification, have appeared, most notably in India, Maldives, and the Philippines.

Case Study: Solar PV Water Pumps in the Dominican Republic[164]

In the Dominican Republic and Honduras, Enersol has used solar PV to pump clean water to communities otherwise dependent on distant, contaminated surface water sources. Since 1993, Enersol has implemented 17 projects through its AguaSol program, placing a premium on maintaining equitable access and on promoting rational water use. A typical community-level system costs $160–170 per beneficiary, based on a 10-year life-cycle cost analysis of the unsubsidized full project costs (water-pumping equipment, civil works, and technical assistance). Those costs work out to $.004 per liter, compared to the $.007 per liter charged for water delivered by private truck. Typical community-member payments cover an "insurance policy" for replacements ($1.25–2.50 per month) and financing of the pumping systems ($2.50–6.25 per month). Communities are responsible for system operation, maintenance, and collection of payments.

To manage costs, Enersol designs systems to pump limited quantities of water used strictly for household consumption. A well-designed system meets the WHO's quantitative standards for improving health, but allows for little waste. Along with the cost savings, water efficiency reduces pumping and consequent drawdown of groundwater, leads to more responsible water use and conservation by beneficiaries, lessens the risk of standing runoff water serving as insect and microbe breeding grounds, and reduces groundwater contamination from runoff and waste water.

Wind-driven water pumps have been used historically to pump water in rural areas, but in the 1950s and 1960s diesel-driven pumps began to take over. Nonetheless, Argentina maintained an interest in building a strong local manufacturing base for small wind turbines. Between 0.5 and 1 million wind-powered water pumps are in use in Argentina. Large numbers of wind-powered water pumps are also used in Africa, including in South Africa (300,000), Namibia (30,000), Cape Verde (800), Zimbabwe (650), and several other countries (another 2,000).[165]

Wind-driven water pumps are reliable systems that require little attention in their operation and have the potential to meet 100 percent of the water requirements for domestic use and production use by a large share of the population in temperate, arid, and cold areas (provided the water can be accessed). As such, they are critical to higher productivity in agricultural and livestock activities and could have a favorable impact on income generation, once the initial investment barrier is surmounted. With good wind resources, wind pumps can be less expensive than other means, particularly if they are manufactured domestically.[166]

Case Study: Wind-driven Water Pumps in Morocco[167]

In 1990, the U.S. Agency for International Development, the Moroccan renewable energy agency (CDER), and the local water department funded the installation of a wind-electric water pumping system in Ain Tolba in northeast Morocco. The 10-kilowatt wind turbine drives an electric pump located in a partially-buried storage tank, supplying water for four communities over a 120-square kilometer area. While the government had previously installed diesel pumps free-of-charge to the local people, five of the six pumps had broken at the time of the wind project and the villagers could not afford the cost of repairs.

When assessed nearly a decade later, the wind-electric system was found to be performing well, providing the four settlements with three times the water they had received from diesel-powered pumps. In one community, Dar el Hamra, the wind system supplied the village with water for the first time in years. The amount of water villagers retrieve from the pumps exceeds demand, enabling them to sell the extra water to other settlements. This additional revenue is then applied towards maintaining the wind turbines.

Studies show that the increase in villagers' time has boosted both the education level and economic status of the village. The project's success has led other settlements to replace their diesel water pumps, and in some cases the way they generate electricity with wind power. Additional smaller wind systems, both for pumping and for electricity, have since been installed in Ain Tolba.

Case Study: Biogas-based Water Supply in India[168]

Less than 30 percent of rural families in India have a source of water at their homes, due in large part to scarcity of energy for motive power. Starting in the mid-1990s, Renewable Energy International-Asia developed a biogas-based REWSU (Rural Electricity and Water Supply Utility) project in nine villages in Karnataka, India. The idea was to replicate REWSUs in many other villages. But by early this decade, all but one of the projects were not operating as designed. REI-Asia decided to undertake a careful assessment beginning in 2003 to understand the reasons for success or failure.

The most successful biogas project to date continues to operate in Mavinakere, a village of 557 people and 202 cattle. Prior to the construction of the biogas-based water-supply plant, villagers were dependent on public hand pumps for domestic water requirements. In the 1970s and earlier, they had to travel 1.5 kilometers to obtain water from a large stone well that has since dried completely. When the biogas-based water-supply plant began operation in 1998, water was supplied to a tap at the doorways of 83 households.

A 2003 survey indicated that the people of Mavinakere remain confident about the plant, having rejected a later government-proposed mini water-supply scheme. Although it was found that the cost of generating electricity from a coal-based thermal plant is less expensive, when the cost of delivering water through the village is also considered, the biogas plant becomes competitive with a centralized water-pumping scheme powered with grid-supplied electricity. Perhaps more importantly, the community prefers the biogas plant because, in addition to providing water more conveniently than the state supply, this system, by being locally managed and operated, allows the users to be in control and avoids losses inherent in delivery from centralized systems.

RETs Can Reduce Greenhouse Gas Emissions

MDG 7 specifies energy efficiency, carbon dioxide emissions, and proportion of forested land as indicators of environmental sustainability. When RETs replace traditional biomass, they contribute to energy efficiency and a reduction in greenhouse gas emissions, furthering the goal of environmental sustainability.

Cutting greenhouse gas emissions is particularly relevant to the developing world, as climate change threatens to disrupt the weakest economies and disadvantage the poorest people. Sea-level rise associated with projected increases in temperature could displace tens of millions of people living in low-lying areas. With climate change, the weakest economies will also be faced with new stresses such as resisting the spread of vector-borne diseases.[169]

Although developing countries produce a fraction of the world's carbon emissions, they can become players in the emerging carbon market if the international community can help develop local capacity and expertise to manage carbon projects. The World Bank's Community Development Carbon Fund (CDCF) links small-scale projects seeking carbon finance with purchasers of verified emission reductions (ERs). For example, the Nepalese Biogas Programme under negotiation will, between 2004 and 2009, install 162,000 small-sized biogas plants. Each biogas plant can reduce 4.6 tons of carbon dioxide equivalent (tCO2e) annually. The CDCF expects to purchase a minimum of 1 million tCO2e with the potential of additional purchase.[170]

Case Study: Biogas-based Cardamom Drying in India[171]

More than 150 growers of large cardamom in Sikkim, India, have been benefiting from biomass gasifier technology in a variety of ways. Sikkim is the largest producer of large cardamom in the world, consuming some 20,000 tons of fuel wood annually. To dry the harvested produce, growers burn wet logs in traditional 'bhatti' (stone and brick ovens) and pass the smoke through a thick bed of cardamom, a tradition practiced all over India. Most large cardamom producers are small farmers who cannot afford higher-cost technologies. And basic problems like difficulty of transportation in hilly areas and un-electrified villages make it harder for them.

The updraft gasifier system, designed and developed by TERI, has the advantage of operating without electricity and is easily transported to hilly areas. The technology provides a healthy working atmosphere with its higher combustion efficiencies and smoke reduction, which in turn saves 50–60 percent of fuelwood. With the rich natural reddish color of the fruit, 35 percent more oil content, and absolutely no burnt smell (which was common in the traditional product), the cardamom is fetching 10-20 percent more in local trading centers. Further, the gasifier systems have the ability to dry large quantities of harvested produce in one, shorter cycle.

The low-cost gasifier system has potential for application in other rural industries. In northeastern India, current activities include lime processing, tea processing, areca nut processing, cashew nut processing, pottery making, fruit processing, turmeric boiling, ginger drying, and yarn dyeing.

Off-grid RETs reduce greenhouse gas emissions, especially when displacing the use of traditional biomass, dirty coal, or diesel generators. However grid-connected RETs and alternative transportation fuels can make a larger contribution to climate change mitigation.

Petroleum-based gasoline and diesel fuel currently account for more than 95 percent of the energy used for transportation around the world, creating a massive market for a clean and renewable substitute.[172] Brazil has already demonstrated a 44-percent replacement of petroleum with ethanol, which has great benefits to air quality, especially in developing countries where vehicle fleets are often old.[173] Other developing countries are planning to ramp up their production of biofuels in the next decade. The Peruvian government, for example, is facilitating the construction of up to 20 distilleries and an ethanol pipeline to export 300 million gallons of ethanol by 2010.[174]

Electricity consumption in developing countries continues to grow rapidly with economic growth, raising concerns about how these countries will expand power generation in the coming decades. According to some estimates, developing countries will need to more than double their current generation capacity by 2020.[175] Existing renewable electricity capacity worldwide totaled 160 GW at the end of 2004, 70 GW of which was installed in the developing world and produced primarily from biomass and small hydropower. This represents only a fraction of the 3,600 GW installed capacity worldwide for all power production.[176]

However, 14 developing countries now have policies to promote renewable power generation, and 9 have set national targets for renewables.[177] China, for example, plans to boost renewable energy to cover 10 percent of its electric power capacity by 2010, raising its green power capacity to 60,000 MW, including 50,000 MW of hydropower and 4,000 MW of wind power. Brazil will add 3.3 GW by 2006 from wind, biomass, and small hydro. Renewables will account for 5 percent of Malaysia's electricity by 2005 and 15 percent of Mali's energy by 2020.[178]

The Kyoto Protocol's Clean Development Mechanism (CDM) creates investment potential for grid-connected renewables in developing countries. For example, India, has implemented a 7.8-MW biomass-based power generation plant using mustard crop residue and direct combustion boiler technology. The generated electricity will replace a mixture of coal- and gas-based power generation, with total carbon emissions reductions expected to be 313,743 tons per year. This CDM project contributes to India's target of 10,000 MW of renewable energy in 2012.[179]

RETs Lead to More Sustainable Agriculture

By boosting agricultural productivity, particularly through irrigation, RETs can increase quality rather than quantity of cultivated land. Use of modern fuels or improved stoves can allow a greater proportion of biomass (in the form of crop residues and manure) to be returned to the soil, allowing nutrient replenishment.[180]

Case Study: Treadle Pumps in Kenya[181]

The MoneyMaker is a treadle irrigation pump designed and manufactured in 1996 by ApproTEC, a non-governmental organization in Kenya. Sold for US $53, the MoneyMaker has been proven to increase the average farmer's productive acreage seven-fold, yielding at least two crop cycles per year instead of one. While the annual income of farms in the country varies from essentially zero to hundreds and even thousands of dollars, Approtec has calculated that the pump increases those earnings by an average of $1,400 a year. The pumps generate a collective total of $50 million a year for their owners—more than half a percent of Kenya's GDP—and have created as many as 25,000 jobs.

CONCLUSION

Access to essential energy services will need to increase for the Millennium Development Goal targets to be met. In some instances, renewable energy technologies can meet needs that conventional approaches cannot. In other circumstances, RETs can provide comparable services more readily than conventional services, and at comparable costs. An energy technology's cost per-unit and its ability to provide essential energy services are the most important indicators of its suitability for poverty alleviation.

Introduction of RETs is frequently hindered by their high cost and the perception that they require heavy government subsidy. While high initial costs are a reality in many circumstances, this is frequently exacerbated by the lack of a competitive energy market and the large subsidies provided to conventional energy systems. The investment patterns of governments and international finance institutions, regulatory frameworks oriented to conventional energy sources, externalization of costs and benefits, and governmental purchasing policies that favor conventional sources are among the obstacles to advancing renewables. If these barriers are overcome and renewable energy production is scaled up, the cost of the new energy options will decline significantly.

The challenge is to create a policy framework that allows renewable energy to be introduced where it makes long-term economic sense, and to allow poor countries to benefit from the declining cost curves that characterize renewable energy markets in many industrial countries. Among the policies that have proven their ability to advance renewables:

Create Supportive Policy and Institutional Frameworks

In his recent book, *The End of Poverty*, Jeffrey Sachs discusses the division of labor between the public and private sector when it comes to financing development and achieving the MDGs. While the private sector "should complement the public investments in human capital," Sachs argues that governments, rather than the private sector, must take responsibility for financing schools, clinics, and roads. Although energy is principally a private business in most countries, providing energy access for rural areas has traditionally been considered an essential public good for which governments are primarily responsible. Government subsidies are typically used to extend electricity grids and provide the poor with petroleum fuels. Providing similar support for renewable energy technologies can help spur their development.

In some countries, governmental awareness of the shortage of public-investment capital for the energy sector has stimulated change in policies to attract private-investment capital. As already mentioned, 42 countries, including 9 developing countries (Brazil, China, Egypt, India, Korea, Malaysia, Mali, South Africa, and Thailand), now have national targets for renewable energy supply. At least 48 countries—34 developed and transition countries and 14 developing countries—now have some type of policy to promote renewable power generation.[182]

Promotion of any source of energy supply, including RETs, should be linked with wider rural development initiatives. RETs are one set of tools to provide a service. Governments are increasingly integrating RETs into electrification plans for rural off-grid energy-service delivery, with health and education applications being important entry points for government intervention.

Governments can also encourage the appropriate use of RETs by supporting compelling and reliable assessments of renewable resources. These assessments increasingly drive supportive policy development and resulting investment. For example, Solar and Wind Energy Resource Assessment (SWERA) is a project of the U.N. Environment Programme, with co-financing from the Global Environment Facility. By assessing wind and solar energy resources using a range of data from satellites and ground-based instruments, SWERA promotes more extensive use of renewable energy resources.[183 †]

Promote Private Sector Involvement

New sources of capital are necessary to meet the growing demand for energy project financing in developing countries. It is currently difficult for RET projects and companies to attract investment because they tend to be small transactions, require more time and effort to bring to investment quality than large conventional projects, and often involve less familiar technologies. Companies also face significant transaction costs in dealing with those investors and with dispersed customer bases in rural areas.[184] Carbon finance through CDMs offers potential co-financing mechanisms, but its high transaction costs will discourage its use for small-scale projects, unless project bundling can be achieved.

Innovative financing mechanisms, particularly when integrated with targeted concessional funding, can help to make renewable energy technologies more attractive for commercial funding and more accessible to customers. Several such mechanisms have been developed to complement cash sales. They include micro-credit from the company, potentially through dealers, or from a third party, such as a micro-finance institution or community-based organization. Either micro-credit approach can involve specially designed credit lines through larger financial institutions, potentially backed by the government.

The new financing mechanisms also include micro-rental or fee-for-service approaches, where all or part of the equipment remains the property of the company, and customers make regular payments for its use. One example is a utility-style concession in which a concessionaire owns the system, charges a monthly fee, and is responsible for the service.[185]

Level the Playing Field

Higher oil prices are creating major problems for countries that subsidize those fuels, threatening economic growth if the subsidies are kept in place and consumer outrage if they are not. In addition to these direct costs, conventional energy sources entail external costs to the environment and human health that can be internalized via levies or taxes. Although this process has met strong resistance in some countries, such economic tools are being used successfully in some countries, particularly in Europe through carbon taxes to internalize the cost of greenhouse gas emissions.[186]

Just as many of the costs of conventional energy are not internalized, markets and policies often fail to internalize the myriad positive externalities—improvements in healthcare, education, communications, employment, etc.—that can result from bringing electricity to underserved areas. Community leaders, local residents, and project developers should seek to explicitly identify such benefits and new growth opportunities. A major hindrance to internalization of costs and benefits is that both are difficult to quantify. The development of reliable methodologies for quantifying externalities would advance the use of RETs.

Nurture Micro-Enterprise

There is growing evidence that RETs can spur the creation of micro-enterprise, stimulating economic development by engaging local people in harnessing energy and providing energy services. Experience shows that the ability of RETs to fight poverty is enhanced when linked with income-generating uses of energy.

The GEF and UNDP recently developed a "Programming Kit on Productive Uses of Renewable Energy" to shape future renewable energy programs in off-grid rural areas of developing countries. This kind of marketing and business support is crucial to the viability of projects targeting productive uses of renewable energy. Energy Service Companies (ESCOs)

[†] In Nicaragua, for example, SWERA assessments of wind resources demonstrated a much greater potential than was previously estimated, prompting the Nicaraguan National Assembly to pass the Decree on Promotion of Wind Energy of Nicaragua 2004, which gives wind-generated electricity "first dispatch," or priority over other options when fed into electricity grids. The U.S. Trade and Development Agency and the Inter-American Development Bank have subsequently launched wind energy feasibility studies in Nicaragua, and wind investment projects are now advancing with 40 megawatts planned in two projects and two more exploration licenses granted.

could be one of the models for promoting productive uses in micro-enterprise. They could also mitigate risk to attract financiers.

Despite the importance of focusing on income-generating uses of energy, targeting business customers alone does not generally create sufficient demand to support a renewable energy industry and infrastructure. Renewable energy projects should instead support both income-generating uses of renewable energy as well as meeting essential human needs for cooking, lighting, heating, and water supply.

Integrate Projects Around Local Needs and Capacity

In order for renewable-energy services to advance the MDGs, they must be part of a multi-sectoral approach, coupled with existing development activities for water, health, education, and entrepreneurship. In particular, project planning should address poor women's needs for reducing labor, improving health, and providing security and income. In many developing countries, reducing indoor air pollution deserves particular attention.

In many situations, the largest consumer of energy services is government. As governments recognize with their own purchasing the values of RETs, costs can be reduced through economies of scale, initial investment costs can be shared with private citizens and companies, and awareness of renewable energy's potential can be more widely disseminated. By integrating renewable energy into rural electrification, rural development, poverty-alleviation, and social welfare programs, the effectiveness of these programs can in many cases be advanced.

Women prepare food under solar street lighting in Burkina Faso

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[179] United Nations Framework Convention on Climate Change, "Biomass in Rajasthan-Electricity Generation From Mustard Crop Residue," Clean Development Mechanism Project Activities, at http://cdm.unfccc.int/Projects/TUEV-SUED1112801052.32/view.html.

[180] U.N. Food and Agriculture Organization, "FAO and Bioenergy" (Rome: April 2000), at www.fao.org/sd/EGdirect/EGre0055.htm.

[181] Lisa Margonelli, "How a Low-cost, Lightweight Pump Is Changing the Economy of a Nation," *Wired Magazine*, April 2002.

[182] REN21, op. cit. note 14, p. 4.

[183] UN Environment Programme, Solar and Wind Energy Resource Assessment Web site, at http://swera.unep.net/swera/index.php.

[184] Rodgers, op. cit. note 57.

[185] Ibid.

[186] European Union Greenhouse Gas Emission Trading Scheme (EU ETS) Web site, at http://europa.eu.int/comm/environment/climat/emission.htm.